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Volunteer Potato (*Solanum tuberosum*) Control with Herbicides and Cultivation in Field Corn (*Zea mays*)[1]

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Abstract: Volunteer potato plants are difficult to control in rotational crops, and they harbor harmful diseases, nematodes, and insects. Five herbicide treatments were evaluated for control of volunteer potato in field corn grown under no-till and conventional tillage in 1994 and 1995. In mid-June, potato control was greater in conventionally tilled corn than no-till corn primarily due to the reservoir tillage that followed postemergence (POST) herbicide applications in the conventional system. Final potato tuber weight was not different between tillage levels in 1994 or 1995. Herbicide treatments reduced potato tuber weight 64 to 96% in no-till corn and 85 to 99% in conventionally tilled corn compared to nontreated checks. Atrazine applied preemergence at 1.1 kg ai/ha followed by dicamba plus 2,4-D applied POST at 0.28 plus 1.1 kg ae/ha, respectively, reduced potato tuber weight greater than 95% in both years and both tillage systems. Corn yield was not affected by tillage level or herbicide treatments in 1994 or 1995 and averaged 10.5 MT/ha in 1994 and 15.1 MT/ha in 1995. In a separate experiment, glyphosate, dicamba plus 2,4-D, or fluroxypyr applied at the eight-leaf stage to potato grown without a corn crop, and followed by cultivation 10 d later, reduced the number of potato tubers produced 79 to 95% compared to nontreated potato.

Nomenclature: Atrazine; cyanazine; 2,4-D, dicamba, dimethylamine salt; fluroxypyr; glyphosate, nicosulfuron; primisulfuron; triclopyr, triethylamine salt; corn, *Zea mays* L 'Pioneer 3394'; potato, *Solanum tuberosum* L. 'Russet Burbank.'

Additional index words: No-till, reservoir tillage (dammer diking).

Abbreviations: DAT, days after treatment; EPOST, early postemergence; LPOST, late postemergence; PRE, preemergence; POST, postemergence; WAT, weeks after treatment.

INTRODUCTION

Field surveys indicate that 106,000 to 460,000 tubers per hectare are left in the soil following a commercial potato harvest (R. A. Boydston, unpublished data; Lumkes 1974; Lutman 1977; Perombelon 1975). Winter soil temperatures in the Columbia Basin of the Northwestern United States, certain maritime regions of Europe, and other regions in the world where potato plants are grown are often not cold enough to adequately kill tubers left in the soil after potato harvest. As a result, potato shoots can emerge in the ensuing crop from overwintering tubers. Volunteer potato plants are difficult to control in rotational crops and can harbor diseases, nematodes, and insects that harm potato crops (Thomas 1983; Wright and Bishop 1981). When volunteer potato plants are allowed to persist in rotational crops, many of the positive effects of crop rotation are lost.

Field corn is a common rotational crop with potato in the Columbia Basin and provides the grower with both cultivation and numerous herbicide options for weed control. A preliminary study was conducted in 1993 to identify herbicides that may control volunteer potato in field corn. Atrazine and cyanazine applied preemergence (PRE) at 1.1 and 0.6 kg/ha caused chlorosis and necrosis on emerging potato plants (unpublished data). Use of sulfonylurea herbicides in cereal crops can persist in soil and injure subsequent potato crops (Moyer 1995; Moyer et al. 1990). Sulfonylurea herbicides nicosulfuron and primisulfuron are labeled for postemergence (POST) applications in corn and suppressed volunteer potato in the preliminary study in 1993. Dicamba and 2,4-D applied POST also suppressed potato, causing epinastic malformed growth (unpublished data). Fluroxypyr has suppressed volunteer potato plants in wheat (*Triticum aestivum L.*) (Oglivy et al. 1989) and onion (*Allium cepa L.*) (Bond 1993; Runham et al. 1993). This herbicide

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injured potato plants when applied POST at 0.22 lb/ha in our preliminary study and has been labeled for emergency use for volunteer potato control in corn. Triclopyr injured potato when applied at rates greater than 100 g/ha (Lobb 1989), suggesting possible options within corn. Cultivation can control volunteer potato plants, but three or four cultivations are required to eliminate them (R. A. Boydston, unpublished data).

The objective of this study was to evaluate volunteer potato control with several promising herbicide treatments with and without cultivation in field corn. Atrazine and cyanazine applied PRE and dicamba, 2,4-D, fluroxypyr, nicosulfuron, primisulfuron, and triclopyr applied POST were tested alone or in combinations for control of volunteer potato in field corn grown under conventional tillage and no-till systems. In a second experiment, several selective and nonselective POST-applied herbicides combined with and without cultivation were tested for potato control.

MATERIALS AND METHODS

Corn Trials. Studies were conducted on a Quincy (Typic Torripsamments) sand, containing 0.5% organic matter, pH 7.0, near Paterson, WA. Whole-seed potato tubers, var. Russet Burbank, averaging 85 g/tuber, were planted March 21, 1994, and March 15, 1995, to simulate volunteer potato plants. Potato tubers were planted with a two-row planter that placed tubers 12 cm deep in 86-cm rows at a density of 71,000 tubers per hectare. Conventionally tilled plots were disked and packed April 23, 1994, and April 18, 1995, prior to planting corn. Pioneer 3394 corn was planted perpendicular to potato rows in four 76-cm rows with a no-till drill on April 25, 1994, and April 27, 1995. Conventionally tilled corn was tilled May 25, 1994, and June 1, 1995. Reservoir tillage,[3] also described as dammer diking, is a common practice in the Pacific Northwest which results in pitted furrows between rows that prevent water runoff. All plots were treated with glyphosate at 1.12 kg ai/ha and metolachlor at 1.7 kg/ha with a field sprayer after planting but prior to emergence of corn. Corn was grown under sprinkler irrigation and was fertilized according to soil tests and university recommendations.

Herbicide treatments were applied with a bicycle-mounted CO_2-pressurized sprayer delivering 190 L/ha at a pressure of 190 kPa through six 8002 XR flat-fan nozzles spaced 51 cm on the boom. PRE treatments (Table 1) were applied April 27, 1994, and May 1, 1995, and incorporated with 1.3 cm of sprinkler irrigation water. POST herbicide treatments (Table 1) were applied May 17, 1994, and May 22, 1995, when potato plants were 18 cm tall with five to six leaves and corn was 18 cm tall with four leaves.

Emerged potato shoots were counted April 27, 1994, and May 11, 1995, in each plot. Potato control was visually rated June 15, 1994, and June 12, 1995 using a scale of 0 to 100%, where 0 = no injury and 100 = plant death. Corn yield was determined by hand harvesting, shelling, and weighing corn from 3 m of the middle two rows of each four-row plot and adjusting to 15% moisture. Potato tuber yield was determined in September by digging and weighing tubers from three randomly placed 50- by 85-cm quadrats from the middle two rows of corn in each plot. In 1995, the number of tubers in each sample was also counted.

The experiment was a split-plot, randomized complete block design with four replications. Main plots were two tillage levels (no-till vs. conventional till) and were 3 by 72 m in 1994 and 3 by 60 m in 1995. Subplots were six herbicide treatments and were 3 by 12 m in 1994 and 3 by 10 m in 1995. Data were tested for homogeneity of variance, subjected to ANOVA, and tested for year by treatment interactions. Treatment means were separated by the LSD test at $\alpha = 0.05$.

Noncrop Trials. A second experiment was conducted to evaluate potato control with several POST herbicides applied at two stages of potato growth. We also included a simulated cultivation 10 days after herbicide treatment (DAT). Whole-potato seed pieces (85 g), var. Russet Burbank, were planted with a two-row planter April 18, 1994, and April 20, 1995, at Paterson, WA. Tubers were placed 12 cm deep in two rows spaced 86 cm apart at a density of 71,000 tubers per hectare. Pendimethalin plus metribuzin, standard herbicides used for weed control in potato crop, were applied PRE at 0.8 and 0.3 kg/ha, respectively, to control annual weeds. Potato plants were grown with sprinkler irrigation under normal potato production practices, and all pests were controlled.

Five herbicide treatments were applied early postemergence (EPOST) when potato shoots were 10 to 20 cm tall with six leaves, and four treatments were applied late postemergence (LPOST) when shoots were 35 to 40 cm tall with eight leaves and 0.5 to 1-cm-diam tubers. EPOST treatments were applied on May 16, 1994, and May 26, 1995, and LPOST treatments were applied on May 24, 1994, and June 7, 1995, with a backpack CO_2-pressurized sprayer delivering 190 L/ha at a pressure of

[3] Reservoir tillage, Ag Engineering and Development Co. Inc., 1515 E 7th, Kennewick, WA 99336.

Table 1. Potato control in mid-June and final potato tuber weight in September in no-till and conventionally tilled corn treated with five herbicide treatments near Paterson, WA, in 1994 and 1995.[a]

Herbicide treatment	Rate[b]	Time of application	Potato control		Potato tuber wt	
			June 15, 1994	June 12, 1995	1994	1995
	kg ai or ae/ha		%		g/m²	
No-till						
		PRE				
Cyanazine	0.8	POST	66	87	555	220
dicamba + 2,4-D	0.28 + 1.1	PRE				
Atrazine	1.1	POST	75	94	67	49
dicamba + 2,4-D	0.28 + 1.1	POST				
Fluroxypyr	0.22		76	94	386	168
Dicamba +	0.28 + 0.05	POST	73	91	296	217
nicosulfuron						
Dicamba +	0.28 + 0.04	POST	78	96	479	185
primisulfuron						
Nontreated check			0	0	1,524	906
		Mean	61	77	552	291
Conventionally tilled						
Cyanazine	0.8		83	94	69	81
dicamba + 2,4-D	0.28 + 1.1	PRE				
Atrazine	1.1	POST	91	96	12	13
dicamba + 2,4-D	0.28 + 1.1	PRE				
Fluroxypyr	0.22	POST	86	96	52	55
Dicamba +	0.28 + 0.05	POST	84	95	201	118
nicosulfuron		POST				
Dicamba +	0.28 + 0.04		86	96	107	96
primisulfuron		POST				
Nontreated check			26	19	1,910	780
		Mean	76	82	392	190
$LSD_{0.05}$ main plot (tillage) means			5.7	2.3	NS	NS
$LSD_{0.05}$ subplot (herbicide) means			4.7	3.7	404	235

[a] Abbreviations: NS, not significant *F* test at 5%; POST, postemergence; PRE, preemergence.

[b] Acid equivalent used for dicamba, fluroxypyr, and 2,4-D.

190 kPa through three 8002 XR flat-fan nozzles spaced 51 cm apart. Ammonium sulfate was added to one glyphosate treatment at 20 g/L spray solution. All other treatments included nonionic surfactant[4] and an organosilicone adjuvant[5] at 0.13 and 0.03% (v/v) spray solution, respectively. Each year, potato shoots were removed at 10 DAT by hand hoeing 4 cm deep in one row of each two-row plot to simulate a cultivation. Potato control was visually evaluated 3 weeks after the last herbicide treatment (WAT) in both years. Potato tubers were harvested on September 15, 1994, and August 16, 1995, from 6 m of each cultivated and noncultivated row. Total tuber number and weight were recorded for each treatment.

The experiment was a split-plot randomized complete block, with herbicides as main plots and tillage regime as subplots. Main plots were 1.7 by 7.6 m, and subplots were 0.9 by 7.6 m. Each treatment was replicated three times. Data were tested for homogeneity of variance prior to ANOVA and tested for year by treatment interactions. Treatment means were separated by the LSD test at $\alpha = 0.05$.

[4] LI-700, phosphatidylcholine, methylacetic acid, alkylpolyoxyethylene ether, and propyl carbinol, Loveland Industries, P.O. Box 1289, Greeley, CO 80632-1289.

[5] Silwet L-77, polyalkyleneoxide modified heptamethylsiloxane, Helena Chemical Company, 7664 Moore Road, Memphis, TN 38120.

RESULTS

Corn Trials. Year by treatment interactions revealed by ANOVA prevented pooling of the data for potato control and potato tuber weight data across years. Therefore, data are presented for each year. Tillage level affected potato control in mid-June 1994 and 1995, but there was no significant tillage by herbicide interaction. Potato control was greater in conventionally tilled corn, which averaged 76 and 82% in 1994 and 1995, respectively, than in no-till corn, which averaged 61 and 77%, respectively, in 1994 and 1995 (Table 1). Increased potato control in the conventionally tilled plots was due, in part, to the reservoir tillage operation that uprooted many potato shoots between the corn rows. Reservoir tillage resulted in 26 and 19% control of potato in the conventionally tilled, nonherbicide-treated checks in 1994 and

1995, respectively, compared to the no-till nontreated checks.

In conventionally tilled corn, shallow disking prior to planting killed all emerged potato shoots. New potato shoots began to emerge within 2 wks after disking. In no-till corn, many potato shoots had emerged and ranged from 1 to 6 cm tall several days after planting corn but before corn emergence. Glyphosate applied PRE to no-till corn killed emerged potato shoots but did not kill the mother tuber and new shoots began to emerge within 2 wks after application. Potato stand counts averaged 0.4 and 2.9/m^2 ($LSD_{0.05}$ = 0.19) in conventionally tilled and no-till corn, respectively, April 27, 1994, and averaged 3.9 and 5.9/m^2 ($LSD_{0.05}$ = 0.82) in conventionally tilled and no-till corn, respectively, May 11, 1995.

In 1994, visual estimates of potato control in mid-June ranged from 66 to 78% with herbicide treatments in no-till plots (Table 1). In 1995, no-till plots, potato control in mid-June ranged from 87 to 96% in herbicide-treated plots. Within no-till corn, a split application of cyanazine PRE followed by dicamba plus 2,4-D POST controlled potato the least. Other herbicide treatments controlled potato similarly, except for dicamba plus nicosulfuron, which controlled potato slightly less than dicamba plus primisulfuron (Table 1).

In 1994 conventionally tilled plots, potato control in mid-June was greatest with atrazine PRE followed by dicamba plus 2,4-D POST (Table 1). All other herbicide treatments controlled potato similarly. In 1995, all herbicide treatments controlled potato equally well in conventionally tilled corn.

Tillage level did not significantly affect final potato tuber weight in 1994 or 1995, but in both years, final tuber weights tended to be lower in conventionally tilled corn than in no-till corn (Table 1). There was no significant tillage by herbicide interaction for final tuber weight. Herbicides reduced tuber weight 64 to 99% in 1994 and 76 to 98% in 1995 compared to the nontreated checks within a tillage treatment. Averaged over tillage levels, all herbicides reduced tuber weight similarly in 1994. Although not significantly different from other herbicide treatments, tuber weight tended to be lowest in treatments of atrazine PRE followed by dicamba plus 2,4D POST both 1994 and 1995.

There was a significant tillage effect on tuber number at P = 0.1, but it was not significant at the P = 0.05 level (Table 2). There was a significant tillage by herbicide interaction effect at P = 0.05 on the number of potato tubers produced (Table 2). Reduction in tuber number ranged from 0 to 91% of the nontreated checks.

Table 2. Final number of potato tubers in corn treated with five herbicide treatments near Paterson, WA, in 1995.[a]

Herbicide treatment	Rate[b]	Time of application	Potato tuber number: No-till	Potato tuber number: Conventionally tilled
	kg ai or ae/ha		No./m^2	
Cyanazine	0.8	PRE	20	8
dicamba + 2,4-D	0.28 + 1.1	POST		
Atrazine	1.1	PRE	8	2
dicamba + 2,4-D	0.28 + 1.1	POST		
Fluroxypyr	0.22	POST	14	6
Dicamba + nicosulfuron	0.28 + 0.05	POST	14	10
Dicamba + primisulfuron	0.28 + 0.04	POST	15	10
Nontreated check			18	23
$LSD_{0.05}$ tillage × herbicide			14.3	

[a] Abbreviations: POST, postemergence; PRE, preemergence.

[b] Acid equivalents used for dicamba, fluroxypyr, and 2,4-D.

Tuber number was not reduced by any of the herbicide treatments tested in the no-till system (Table 2). Fluroxypyr applied POST and atrazine or cyanazine PRE followed by dicamba plus 2,4-D POST reduced tuber number from 65 to 91% in conventionally tilled corn (Table 2). Percentage reduction in tuber number by herbicides relative to the nontreated check was less than reduction in tuber weight (Table 1).

Corn yield was not affected by tillage or herbicide treatments in 1994 or 1995 and averaged 10.5 MT/ha in 1994 and 15.1 MT/ha in 1995 (data not shown). All herbicides applied POST injured corn slightly for several weeks after application (data not shown). In this study, potato plants that were not controlled in nontreated checks did not decrease final corn yields. Early-season competition from potato was reduced by disking prior to planting in conventionally tilled corn and by glyphosate application in no-till corn. Later season competition from potato was reduced from shading by the corn crop and by Colorado potato beetles (*Leptinotarsa decemlineata*), which severely defoliated many of the surviving potato plants. None of the herbicide treatments tested eliminated potato, but reasonably good control was achieved with all herbicides, especially when followed by a reservoir tillage operation.

Noncrop Trials. Year by treatment interaction was not significant (P = 0.05) for potato control and weight or numbers of potato tubers produced, so data from 1994 and 1995 are combined. There was a significant herbicide by hoeing interaction effect on weight and numbers of potato tubers produced (Table 3). All herbicide treatments injured potato foliage 3 WAT and reduced final potato tuber weight compared to the nontreated, noncultivated check (Table 3). However, with the exception of

Table 3. Visible potato control and weight and number of potato tubers produced on plants treated with several herbicides applied at the six- and eight-leaf stages of potato, with and without removing emerged shoots by hoeing at 10 d after herbicide applications. Data are average of 1994 and 1995 combined data.

Herbicide treatment	Time of application	Rate[a]	Control mid-June	Weight of potato tubers		Number of potato tubers	
				Not hoed	Hoed	Not hoed	Hoed
		kg ai or ae/ha	%	g/m²		No./m³	
Dicamba + 2,4-D	6-leaf	0.28 + 1.1	73	2,240	1,260	64	22
Fluroxypyr	6-leaf	0.22	53	3,150	2,760	47	39
Triclopyr	6-leaf	1.1	28	5,270	1,550	77	23
Glyphosate	6-leaf	0.7	84	2,230	1,340	38	17
Glyphosate + NH_4SO_4[b]	6-leaf	0.7	88	1,300	1,020	23	12
Dicamba + 2,4-D	8-leaf	0.28 + 1.1	63	3,360	70	89	5
Fluroxypyr	8-leaf	0.22	83	2,320	110	58	9
Glyphosate	8-leaf	0.7	85	1,140	170	106	3
Glyphosate + NH_4SO_4	8-leaf	0.7	88	710	170	42	2
Nontreated			0	8,330	2,560	65	43
		$LSD_{0.05}$	8.1	659		28	

[a] Acid equivalent used for dicamba, fluroxypyr, triclopyr, and 2,4-D.

[b] Ammonium sulfate (NH_4SO_4) added at 20 g/L spray solution.

glyphosate plus ammonium sulfate applied at the six-leaf stage, herbicides applied without an ensuing cultivation did not reduce final tuber number. Hoeing potato shoots 10 DAT reduced both number and weight of tubers formed compared to herbicides alone in all treatments except fluroxypyr, glyphosate, and glyphosate plus ammonium sulfate applied at the six-leaf stage, herbicides applied without an ensuing cultivation did not reduce final tuber number. Hoeing potato shoots 10 DAT reduced both number and weight of tubers formed compared to herbicides alone in all treatments except fluroxypyr, glyphosate, and glyphosate plus ammonium sulfate applied at the six-leaf stage. Final tuber weight was reduced the most when herbicides were applied at the eight-leaf stage followed by a cultivation 10 DAT compared to the nontreated, noncultivated check (Table 3). Tuber number was reduced similarly for herbicides applied at the six- or eight-leaf stage and followed by a cultivation, except for fluroxypyr, which reduced tuber number more applied at the eight-leaf stage than at the six-leaf stage.

Dicamba plus 2,4D injured potato foliage at 3 WAT. Without cultivation, dicamba plus 2,4-D reduced tuber weight more when applied at the six-leaf stage than at the eight-leaf stage of potato. Triclopyr applied at the six-leaf stage of potato and without cultivation injured potato foliage the least and reduced final tuber weight the least. However, triclopyr applied at the six-leaf stage of potato followed by cultivation reduced potato tuber weight and tuber number equal to dicamba plus 2,4-D or glyphosate applied at the six-leaf stage followed by cultivation.

Fluroxypyr injured potato foliage and reduced weight of tubers more when applied at the eight-leaf stage of growth than at the six-leaf stage of growth (Table 3). Fluroxypyr reduced the number of tubers produced only when applied at the eight-leaf stage of growth followed by cultivation. Similar results were observed in wheat when fluroxypyr applications were delayed (Bevis and Jewell 1986).

Glyphosate visibly injured potato shoots more than other herbicide treatments applied at the six-leaf stage of growth and more than dicamba plus 2,4-D at the eight-leaf stage of growth (Table 3). Glyphosate reduced final tuber weight more when applied at the later growth stage, after daughter tubers had begun to form. In previous research, glyphosate did not control potato well when applied to early stages of potato development (Lutman and Richardson 1978; Oglivy et al. 1989). Smid and Hiller (1981) reported glyphosate caused abnormal sprouts from mother tubers when applied prior to tuber initiation, but they did not evaluate sprout development beyond 14 d in their field trials. Including ammonium sulfate with glyphosate did not increase potato injury but decreased potato tuber weight when applied at the six-leaf growth stage without cultivation. Lutman and Richardson (1978) reported increased injury to potato with glyphosate when ammonium sulfate was added, but studies were limited to greenhouse trials. Final potato tuber number and weight tended to be less when ammonium sulfate was applied with glyphosate than when glyphosate was applied with a surfactant, although differences were significant only when applied at the six-leaf stage.

Results from the noncrop studies indicate that cultivation about 10 d after a POST-applied herbicide reduces the weight and number of tubers produced. The lack of cultivation effect on final tuber weight in the corn trials was probably a result of late-season competition with potato by corn and mid-season infestation of Colorado potato beetles, which substantially defoliated potato shoots that escaped herbicide and cultivation treatments. In the corn trials, atrazine applied PRE followed by dicamba plus 2,4-D applied POST consistently controlled volunteer potato and greatly reduced final potato tuber weight and number of tubers. Potato is grown every 3 or 4 yr in most rotations, and atrazine could be used for volunteer potato control in the year following potato without carryover concerns to the next potato crop. However, soil persistence of atrazine restricts crop rotation options to nonsensitive crops the year following atrazine application.

Controlling volunteer potato requires an integrated approach that includes timely application of herbicides, cultivation, and crop competition. Combining these tactics can significantly reduce the weight and number of potato tubers formed in the rotation crop, thereby reducing the potential of volunteer potato in the following crop.

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